MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

EPM4066 – ROBOTICS AND AUTOMATION
(ME)

9 MARCH 2018
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1.This Question paper consists of 6 pages including cover page with 4 Questions only. DH-parameter procedures are included in Appendix.

2. Attempt **ALL** questions. All questions carry equal marks and thedistribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Define the terms "Direct and Inverse Kinematics". [4 marks]

(b) For the 3-DOF (RPR) manipulator arm shown in Fig Q1,

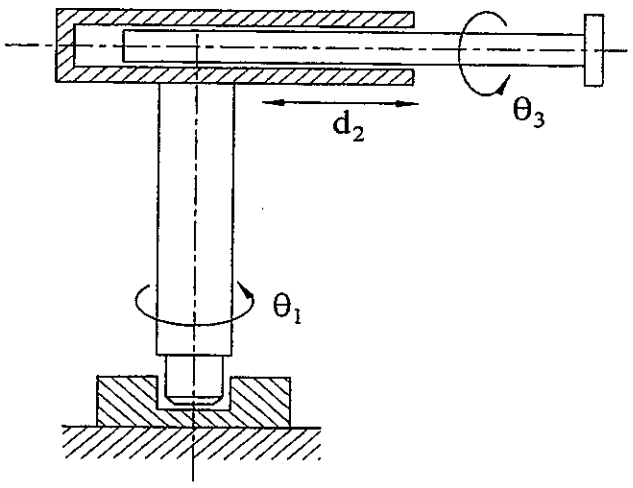

Fig Q1

(i) Determine the frame assignment. [4 marks]

(ii) Determine the joint link parameter. [4 marks]

(iii) Obtain the overall homogeneous transformation matrix. [7 marks]

(c) With a given tool pose $T_{base}^{tool} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & p_1 \\ r_{21} & r_{22} & r_{23} & p_2 \\ r_{31} & r_{32} & r_{33} & p_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$, solve the inverse kinematics equations to find the joint variables q. [6 marks]

Continued...

Question 2

(a) Describe briefly the three different levels of intelligence.

[3 marks]

(b) Briefly explain and sketch the three safety zones in a work cell.

[5 marks]

(c) One of the joints of an articulated robot has moved from initial angle of 30° to a final angle of 75° in 5 seconds. The robot starts from rest, and it has a final velocity of 3 degrees/sec. Calculate the coefficients for a third order polynomial joint space trajectory and hence, determine its initial and final joint accelerations.

[9 marks]

(d) Given the Cartesian coordinates of a point p as (20, 24, 28), calculate the base angle, the complete shoulder angle and the elbow angle for a jointed-arm robot if the upper arm is 24 cm long and the forearm is 22 cm long as shown in Fig Q2.

[8 marks]

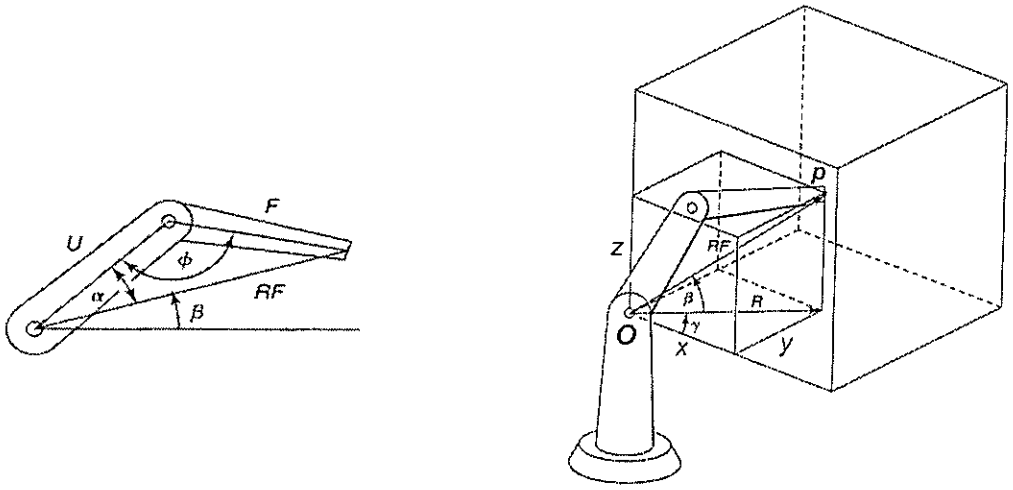

Fig Q2

Continued...

Question 3

(a) The link-coordinate diagram of a 3-axis planar articulated robot is shown in Fig Q3:

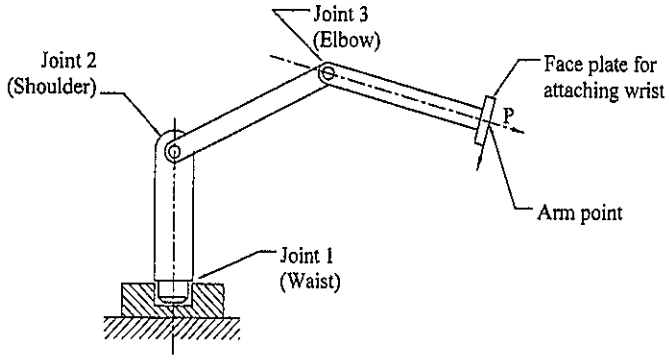

Fig Q3

Given the transformation matrices of the robot as:

$$T_0^1 = \begin{bmatrix} C_1 & 0 & S_1 & 0 \\ S_1 & 0 & -C_1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T_0^2 = \begin{bmatrix} C_1C_2 & -C_1S_2 & S_1 & C_1L_2C_2 \\ S_1C_2 & -S_1S_2 & -C_1 & S_1L_2C_2 \\ S_2 & C_2 & 0 & L_2S_2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T_0^3 = \begin{bmatrix} C_1C_{23} & -C_1S_{23} & S_1 & C_1(L_3C_{23}+L_2C_2) \\ S_1C_{23} & -S_1S_{23} & -C_1 & S_1(L_3C_{23}+L_2C_2) \\ S_{23} & C_{23} & 0 & L_3S_{23}+L_2S_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Where C_{23} and S_{23} symbolize $\cos(\theta_2+\theta_3)$ and $\sin(\theta_2+\theta_3)$, respectively

(i) Obtain the tool configuration vector *W(q)*. [3 marks]

(ii) Find the tool Jacobian matrix, *V(q)*. [8 marks]

(b) What are the basic reasons for using sensors in work cell? [4 marks]

(c) Why is it important to introduce special measures to control robotic arm? [4 marks]

(d) Describe three major methods for programming robots. [6 marks]

Continued...

Question 4

(a) Define "automation" and give five reasons for automating in automation industry.

[4 marks]

(b) Briefly explain the following types of automation and their typical features.

(i) Fixed automation

[2 marks]

(ii) Programmable automation

[2 marks]

(c) A manufacturing company plans to invest on a new automation machine which will cost RM100,000. The cost of operating and maintaining the automation machine will be roughly RM30,000 per year. The expected revenue is estimated as RM60,000 per year for 7 years. At the end of 7 years, the machine will be scrapped at zero salvage value.

(i) Determine payback period/ROI (Return of Investment) in years.

[4 marks]

(ii) Find the equivalent uniform annual cost for the project. By using rate-of-return criterion of 20% determine the equivalent present worth of the proposal.

[4 marks]

(d) A manually operated production machine costs RM 50,000. It will have a service life of 10 years with a negligible salvage value at end of its service life. The machine produces parts at a rate of 25 units / hour. The annual maintenance cost for the machine is RM 5,000. A machine overhead rate of 10% is applicable to capital cost and maintenance. Labor to run the machine costs RM 10.00 / *h* and the applicable overhead rate is 25%. Determine the profit break-even point if the value added is RM2.50 / unit and the rate-of-return criterion is 20%.

[9 marks]

Continued...

Appendix

Procedure to DH-Parameter

1. Number the joints from 1 to n starting at the base and ending with the tool yaw, pitch and roll, in that order.
2. Assign a right-handed orthonormal coordinate frame L_0 to the robot base, making sure that z^0 aligns with the axis of joint 1. Set $k=1$.
3. Align z^k with the axis of joint $k+1$.
4. Locate the origin of L_k at the intersection of the z^k and z^{k-1} axes. If they do not intersect, use the intersection of z^k with a common normal between z^k and z^{k-1}.
5. Select x^k to be orthogonal to both z^k and z^{k-1}. If z^k and z^{k-1} are parallel, point x^k away from z^{k-1}.
6. Select y^k to form right-handed orthonormal coordinate frame L_k and set $k = k+1$. If $k<n$, go to step 3; else continue.
7. Set the origin of L_n at the tool tip. Align z^n with the approach vector, y^n with the sliding vector
   and x^n with the normal vector of the tool. Set $k=1$.
8. Locate point b^k at the intersection of the x^k and z^{k-1} axes. If they do not intersect, use the intersection of x^k with a common normal between x^k and z^{k-1}.
9. Compute θ_k as the angle of rotation from x^{k-1} to x^k measured about z^{k-1}.
10. Compute d_k as the distance from the origin of frame L_{k-1} to point b^k measured along z^{k-1}.
11. Compute a_k as the distance from the point b^k to the origin of frame L_k measured along x^k.
12. Compute α_k as the angle of rotation from z^{k-1} to z^k measured about x^k.
13. Set $k = k+1$. If $k \leq n$, go to step 8; else stop.

Generic DH-Transformation Matrix

$$T_{k-1}^{k} = \begin{bmatrix} C\theta_k & -S\theta_k C\alpha_k & S\theta_k S\alpha_k & a_k C\theta_k \\ S\theta_k & C\theta_k C\alpha_k & -C\theta_k S\alpha_k & a_k S\theta_k \\ 0 & S\alpha_k & C\alpha_k & d_k \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

End of Paper